Introduction

- Established practice and previous literature impose a 10 msec limit on hearing-aid throughput delay (Herbig & Chalupper 2010).
- Larger delays are objectionable due to interaction between amplified and direct acoustic paths.
- The delay limit severely impacts the amount of processing that can take place in a hearing aid.
- Previous studies looked at the effect of delay in laboratory conditions using a high signal-to-noise ratio.
- The current study tests the validity of this delay limit under noisy, real-world listening conditions.

Background

- Combinations of acoustic paths with different delays contribute to (in)tolerances.
- Tolerable delays during speech production (Stone & Moore, 2001)
  - 14-30 msec
  - Acclimatization is a factor
- Tolerable delays with open fittings (Stone et al., 2008)
  - As low as 5-6 msec
  - Hearing threshold and direct-to-amplified path ratio are factors
- Common practice: limit overall delay to 10 msec
- Limits constrain signal processing capabilities:
  - Number of frequency bands or bins
  - Signal processing (beamforming, noise reduction)
  - Binaural processing (beamformer)
  - Remote microphone communication

Methods

Research Questions:
When comparing hearing-aid throughput delays of 4.5, 10, 15 and 20 msec in background noise levels greater than 70 dB SPL:
1. Are normally hearing listeners able to detect differences between the delays?
2. Do normally hearing listeners find the delays acceptable?

Participants:
Ten normally hearing listeners compared processing delays ranging from 4.5 to 20 msec under conditions where the background noise level was 70 dB SPL or greater

Hearing Aid Devices:
- Starkey Xino RIC devices with firmware that allows throughput delay to be parameterized.
- Receivers were fit with non-occluding earbuds.
- Gain prescription was best-fit with Starkey eStat for a 30-dB flat hearing loss.
- Four memories were programmed identically except for throughput delay:
  - Memory 1 contained the standard 4.5 msec delay
  - Memories 2-3 contained randomized delays of 10, 15 and 20 msec

Procedure:
- Participants listened to Memory 1 (4.5 msec delay) in all normal/quiet listening conditions.
- Participants sought out noisy situations (crowds, restaurants, malls, etc.).
- Noise level was assessed using a calibrated sound meter app on a hand-held device.
- Participants compared Memories 2-4 to Memory 1 in noisy situations while listening to and perceiving environmental sounds, speech of others and their own voice.
- Participants logged perceived differences and acceptability of each memory in each listening situation.

Results

- Ten participants reported on 104 listening trials.
- Background noise levels ranged from 65-95 dB SPL
- Four of ten participants perceived no difference across all delays.
- General differences were observed in 33/104 trials (6/10 participants) for delays ≥ 10 msec:
  - 9(4) @ 10 msec;
  - 9(5) @ 15 msec;
  - 15(6) @ 20 msec
- Qualitative reports of sound quality included descriptions of phasing, reverber, echo, “stretched-out”
- Own-voice differences were observed in 12/104 trials (5/10 participants) for delays ≥ 10 msec:
  - 3(2) @ 10 msec;
  - 1(1) @ 15 msec;
  - 8(4) @ 20 msec

- Nine of ten participants reported all latencies as acceptable in at least one trial.
- All latencies were reported as acceptable at noise levels > 80 dB SPL
- Unacceptable delays were reported in 6/104 trials (3/10 participants):
  - 1(1) @ 10 msec;
  - 3(1) @ 15 msec;
  - 1(2) @ 20 msec

Discussion

- Other factors affected by delay:
  - Audio-visual asynchrony
  - Lip-readers tolerate up to ~40 msec delay.
  - Tactile-acoustic interaction
  - Impulsive sounds from cutlery, keyboards, etc. are impacted by hearing-aid throughput delay.

- Laboratory control vs real-world conditions:
  - Difficult to control for sound level in real-world environment.
  - Difficult to recreate true noise environment and communication scenarios in laboratory environment.

- Other factors may affect perception and acceptable throughput delay:
  - Hearing impairment
  - Acceptance of a particular delay may depend on conditions of improved speech intelligibility.

Summary

- Our data suggests that listeners can tolerate longer than established hearing-aid processing delays under noisy listening conditions.
- Some listeners could detect differences in throughput delay but most found delays up to our maximum-tested 20 msec to be acceptable in noise.
- Future work will examine the effect of hearing impairment and trade-offs with SNR improvements.

References


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